WRITTEN STATEMENT
BY
DR. THOMAS R. KARL
DIRECTOR
NATIONAL CLIMATIC DATA CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)
U.S. DEPARTMENT OF COMMERCE

BEFORE

THE COMMITTEE ON APPROPRIATIONS
UNITED STATES SENATE
FIELD HEARING IN ANCHORAGE, ALASKA
ON
COASTAL EROSION AND FLOODING IN ALASKA

JUNE 29, 2004

Mr. Chairman and Members of the Committee: As Director of the National Climatic Data Center, which is part of NOAA's Satellite and Information Services, and Program Manager for NOAA's Climate Observations and Analysis Program, I am pleased to have the opportunity to testify before you today. NOAA has a variety of climate observing systems, data, and computer models to help us understand climate variability and change as it relates to coastal erosion and flooding in Alaska.

Climate Change in the Arctic

The Intergovernmental Panel on Climate Change (IPCC) stated that most of the observed warming over the past 50 years is likely to have been due to the increases in greenhouse gases, and this was generally agreed to by the National Research Council (NRC) in its report to President Bush in 2001. However, as also pointed out by the NRC and the IPCC the science of climate change does have a degree of uncertainty that will make predictions subject to many revisions in the future.

The Arctic is recognized as the area of the world where changes to the climate are likely to be the largest, and is also an area where natural variability has always been large. Current climate models predict a greater warming for the Arctic than for the rest of the globe. The amount of warming would lead to significant impacts. The projections of future changes however, are complicated by possible interactions involving stratospheric ozone, human-induced atmospheric aerosols, and changes in other parts of the Arctic system. For this reason, current estimates of future changes to the Arctic vary significantly among climate models. The model results disagree as to both the magnitude of changes and the regional aspects of these changes. We also know that the Arctic undergoes considerable natural climate variation on decadal and longer time scales and this must be considered in addition to any anthropogenic change.

As an outgrowth of discussions among NOAA, the Arctic Council and the International Arctic

Science Committee, and the National Science Foundation in FY2000, it was agreed that the International Arctic Research Center (IARC) could be the site for the Secretariat of a new international activity, the Arctic Climate Impact Assessment (ACIA). As an activity of the Arctic Council, the ACIA is nearing completion. Scientists from all eight Arctic countries have contributed to its completion. NOAA is the minor co-sponsor of the ACIA, while the National Science Foundation is providing the major support to the ACIA through the IARC. The Secretariat for the ACIA is located at the University of Alaska and is headed by Dr. Gunter Weller, who is also Director of NOAA's Cooperative Institute for Arctic Research.

The ACIA will result in improved knowledge regarding past climate variability and change over the entire Arctic, projections of Arctic climate variability in the future, and an evaluation of the impacts of climate variability and change on the biological environment, human uses of the environment, and social structures. The Arctic Council will use this knowledge to prepare a policy report discussing actions that governments should consider in response to anticipated changes in Arctic climate. More information on ACIA can be found on its website at http://www.acia.uaf.edu

Climate Considerations Related to Coastal Erosion and Flooding in Alaska

There are a variety of climate variables that can directly affect coastal erosion. Our degree of uncertainty regarding how these variables are changing and could change over the course of the 21st Century is not uniform from variable to variable. For climate monitoring, this uncertainty arises from the length of the data record, its spatial and temporal resolution, as well as the capability of instruments used to measure climate-related change. Many of our long-term climate model projections are also subject to considerable uncertainty. Climate variables of particular interest related to coastal erosion and flooding include: (1) sea ice, snow cover, and permafrost extent all directly driven by temperature change and to some extent by atmospheric and oceanic circulation; (2) storminess as related to wave height and storm surges, (3) precipitation and related snow and ice cover, and (4) sea level as related to land ice, ocean temperature, and movement of the land relative to the ocean owing to geologic features and glacial rebound of the land as land ice melts.

Generally, sea ice extent is important because it thwarts ocean wave energy. Wave energy is dependent on distance traveled by the wind over open water. Less extensive sea ice exposes the coastline to more frequent and potentially higher ocean waves and swells. Temperature drives the extent of sea ice, but changes in atmospheric and ocean circulation also play an important role in understanding multi-year variations of sea ice extent. Changes in precipitation type, amount and intensity as well as snow and ice cover extent, can also contribute to coastal erosion from stream flow and overland runoff to the sea. Loss of permafrost along coasts can lead to subsidence of the land that occurs when ice beneath the sea and along the shoreline melts. Alaska has considerable permafrost along its northern and western coasts. The height of the sea relative to the land is the ultimate long-term driver for coastal erosion, but Alaskan sea level rise is complicated by both climatic factors and geologic forces affecting local and regional changes in the height of the land relative to the ocean.

Atmospheric Temperature

Temperatures in Alaska have increased. Observed data indicate that Alaskan spring and summer surface temperatures have increased by about 2 to 3 degrees Celsius (about 4 to 5 degrees Fahrenheit) in the last few decades. However, there are no discernible trends of temperature during autumn, and changes in winter temperature are more complex. There were two five-year periods in the first half of the 20th Century when temperatures were nearly as warm as today, but during recent decades record-breaking high temperatures have become more common.

Although the number of reporting stations in Alaska is quite low relative to our station network in mid-latitudes, the data uncertainties are not large enough to overwhelm the increases observed. Additionally, NOAA has now established two Climate Reference Stations to help discern any acceleration or deceleration of current temperature trends.

Most climate model projections for temperature change during the 21st Century suggest that Alaska, and the Arctic as a whole, will warm at least twice as much as the rest of the world. The warming is expected to be largest during the cold half of the year. The observed lack of warming during the autumn and the relatively large increases during other times of the year is not entirely consistent with model projections. They do not depict this asymmetry. This suggests we require more observations, and better and higher resolution models.

As temperatures increase and more sea ice is melted, a natural climate feedback occurs, due to the less reflective character of the ocean formerly covered by sea ice. These feedbacks can lead to an accelerated warming and additional sea ice melting. For example, the average of the five models used in the Arctic Climate Impact Assessment project substantial reductions in summertime sea ice around the entire Arctic Basin, with one model projecting an ice-free Arctic in the summer by the middle of this century. On average, the climate models project an acceleration of sea ice retreat, with periods of extensive melting spreading progressively further into spring and fall.

Sea Ice Extent

Large portions of Arctic sea ice form during the cold seasons and melt during the warm seasons. Considerable sea ice persists through the melt-season, but due to ocean circulation and the resultant movement, multi-year sea ice makes up only a fraction of the total ice extent. Our records indicate that the formation of new sea ice each year cannot keep up with the rate of melting. This melting is consistent with observed surface warming. Arctic sea ice has been steadily decreasing since the 1950s, measured largely from continuous coverage provided by NOAA polar orbiting satellites beginning in the 1970s. Prior to that time, assessment of Arctic sea ice extent during the first half of the 20th Century was limited to reports from land stations and ocean surface observations. We have less confidence in the data from the first part of the Century, but independent anecdotal evidence, such as interviews with native peoples of Alaska, also suggests substantially greater sea ice extent during this time. NOAA is working to increase our sea ice monitoring capability through ice-tethered buoys to determine sea ice thickness and other key aspects of sea ice.

It is important to understand the trends of coastal sea ice extent since sea ice extent is an important determinant of wave energy affecting coastlines. As the storms which create wave energy also have a strong component of seasonality, it is important to know how sea ice is changing by season. In the Pacific, major extra-tropical storms occur most frequently during autumn through spring. Since the 1950s, sea ice extent during winter and autumn has decreased from 15 to 14 and 12 to 11 million square kilometers, respectively. Since the 1950s, decreases in spring and summer are substantially greater, down from an average of 15 to 12 and 11 to 8 million square miles, respectively. This is equivalent to more than 10% of the North American land mass and is a larger area than the State of Alaska. At the present rate of decrease, the Arctic would be ice-free in summer during the first half of the 22nd Century. All climate models project this trend to continue regardless of the emission scenario used and the sensitivity of the model.

Storms

The climatology of Pacific Ocean storms favors the development of the strongest storms (extra-tropical cyclones) from autumn to spring. Although there are remaining uncertainties in the quality of data, analyses of Pacific Ocean extra-tropical cyclones over the past 50 years indicate little change in the total number, but a significant increase in the number of intense cyclones (storms with low central pressure and resultant high winds and waves). The increase in extra-tropical storms is punctuated with considerable year-to-year variability. The extent to which the increase in intense cyclones is related to global warming remains uncertain, although there is some evidence to suggest as the world warms the intensity of cyclones could increase. But because there are competing factors that act to cancel each other, the case for an increase in cyclone intensity is yet to be settled. Similarly, our ability to remove biases in the data also remains uncertain owing to more plentiful data on storm intensity in recent decades.

Regardless of whether intense cyclones are increasing in number or whether they will increase in the future, the greater expanse of open water with less extensive sea ice means that ocean waves with resultant coastal erosion can occur more frequently and with greater impact.

Precipitation and Snow Cover Extent

One of the most difficult quantities to measure across the State of Alaska is precipitation. This is due to the variable nature of precipitation in general, the relatively low number of observing stations across the State, and the difficulty of providing high-quality data in the harsh Arctic environment. Over time, we anticipate that NOAA's Climate Reference Network and the modernization of NOAA's Cooperative Observing Network could help to alleviate this problem.

Based on existing records, however, there is evidence to indicate that during the past 40 years as temperatures have warmed, more precipitation is now falling in liquid form (rain) as opposed to solid form (snow, ice). The quantity of precipitation has also increased during the 20th Century, with much of that occurring during the recent period of warming over the past 40 years. The increase is estimated to be between 10 to 20% with most of the increase occurring during the summer and winter as opposed to the transition seasons. Owing to greater overall precipitation in the summer, the percent increase in summer equates to a greater quantity of precipitation compared to winter.

The large uncertainty in the estimated precipitation trends is, in large part, attributed to the low density of observing stations, but also stems from the difficulty of measuring wind-blown solid precipitation. Analyses of changes in heavy precipitation events have been conducted for areas south of 62 degrees north latitude, and they show that the frequency of heavy precipitation events has substantially (30 to 40%) increased during the past several decades. Additionally, a disproportionate amount of the precipitation increase is attributed to the heaviest precipitation events.

Climate models project that precipitation will increase by a greater proportion in the high latitudes compared to the rest of the world. This is consistent from model to model, as is the fact that this increase is expected to be disproportionately large in the heavier precipitation events. Both can lead to increased erosion.

NOAA's polar-orbiting environmental satellite data and surface-based observations have also observed major changes in snow cover extent. North American snow cover extent has decreased by about 1 million square kilometers and this trend is expected to continue or accelerate. Surface observers also report a one to two week reduction in the number of days with snow on the ground across the State. In addition, in the Arctic, the lake and river ice season is now estimated to be 12 days less compared to the 19th Century

The increase in total precipitation and liquid precipitation, especially when falling on less extensive snow cover, can affect soil erosion. However, the complicated effects of changes in precipitation type and intensity, earlier break-up of winter ice, and less extensive snow cover have not been well evaluated with respect to potential impacts on coastal erosion and flooding. It will be necessary to know which factor dominates in order to understand whether coastal erosion and flooding will be enhanced or ameliorated due to changes in precipitation and snow cover extent.

Permafrost

The thawing of the permafrost, especially along the northern coasts, is expected to continue. Long-term measurements of temperatures within the permafrost are rare, but it is clear that as the air and ocean temperatures have warmed permafrost is also melting. As permafrost melts along the coastlines the effect on coastal erosion can be compounded by sea ice retreat. The thaw causes the land to subside along the shore exposing more land to the action of the waves.

Sea Level

As ocean temperatures warm and glacial ice melts, global average sea level is increasing. Sea level rise during the 20th Century is estimated to be between 0.1 and 0.2 meters. To put this in context, the Intergovernmental Panel on Climate Change (IPCC) estimates that during the last 6,000 years, global average sea level variations on time-scales of a few hundred years and longer are likely to have been less than 0.3 to 0.5 meters. The IPCC also notes that no significant acceleration in the rate of sea level rise during the 20th century has been detected.

Under a scenario of climate warming, climate models project changes in sea level by the end of the 21st Century of between 0.1 to 0.9 meters. This large range is related to uncertainties regarding increasing snowfall in Greenland and Antarctica as the climate warms (warm air can hold more water vapor leading to heavier snowfall when temperatures are below freezing) versus the rate of melting due to warming. Generally, increases in sea level are projected by climate models to be higher in high latitudes. Such a general increase in sea level would expose more land to coastal erosion through wave energy and storm surges.

However, it is important to recognize that there are many local and regional variations of sea level rise and such variations are no exception in Alaska. Complications arise due to geologic forces, the rebound of the land as glaciers melt and, in some areas, local engineering projects. For some areas in Alaska, sea level is actually falling due to natural geologic and glacial rebound effects, (e.g., parts of Southeast Alaska), but this is generally not the case in much of Alaska. The global rise in sea level is due to both melting of land ice and the thermal expansion of ocean water. There are other factors that also play a role in sea level such as the amount of water held back by human-made land reservoirs, leading to sea level falls, but this effect does not dominate.

NOAA maintains a global network of tide gauges that have provided the only data to calculate global sea-level rise prior to the satellite era. High quality tide-gauges are a high priority within NOAA to ensure adequate reference points to gauge sea level changes. NASA, in cooperation with our French partners, has been flying a satellite altimeter as part of their Topex/Poseidon and JASON missions. These missions provide high precision global sea level data when calibrated with NOAA and other country tide-gauges. Recent analyses of these data suggest that global sea level may have accelerated its increase during the 1990s by a factor of two or more compared to increases. Additional data will be required to confirm such a trend, and points to the importance of continuing satellite altimetry missions and maintenance and expansion of global tide gauges.

Conclusion

Changes in Alaskan climate are among the largest in the world. They have likely played an important role in determining the extent of coastal erosion and flooding in Alaska and are likely to continue to do so in the future. Accelerated coastal erosion and flooding in Alaska cannot be ruled out.

NOAA has numerous climate monitoring, data management and analyses, and climate modeling activities that should help us understand, adapt and mitigate the impact of climate variability and change on the State of Alaska.

Thank you, Mr. Chairman for allowing me to contribute to this important hearing. I look forward to answering any questions you might have.